# Illuminating Ideas Innovations in Solid State Lighting



## Developments in Solid State Lighting

Breakthroughs in light emitting diode (LED) and organic light emitting diode (OLED) technology are catalyzing advances in solid state lighting (SSL). Once used only for indicator lights, SSL technology is now replacing conventional lighting in traffic lights, exit signs, mobile phone and digital camera displays, and other niche applications. Research to achieve further technology advances is well under way, driving toward development of an efficient, full-spectrum light source that will replace low-efficiency incandescent and fluorescent lamps used for general illumination.

The U.S. Department of Energy (DOE) has invested in solid state lighting technology research and development since 2000. In this short time frame, DOE researchers have made dramatic progress, achieving several world records.

One project led to the development of the brightest and most luminous polymer OLED, with the highest color rendering index in its class. Another project developed the world's most efficacious white light LED.

DOE supports R&D in six key areas: quantum efficiency, longevity, sustainability and control, packaging, infrastructure, and cost reduction. Advances in these key areas will result in SSL technologies that can compete in the general lighting market and deliver significant energy savings.



Through a series of interactive workshops, DOE and SSL partners have developed an extensive research agenda targeting technology improvements in six key areas. These ongoing workshops provide an interactive forum to ensure that DOE funds the appropriate research topics to accelerate SSLin the market.



## Lighting the Way to Energy Savings

In the next few decades, general illumination technology will undergo a remarkable transformation through improvements in solid state lighting. No other single lighting technology offers so much potential to conserve precious electricity, and at the same time, enhance the quality of our building environments.

However, major research challenges must be addressed before the full promise of solid state lighting is realized. In partnership with industry leaders, research and academic organizations, and national laboratories, the U.S. Department of Energy is working to accelerate technology developments that will profoundly change the future of lighting. These collaborative, cost-shared efforts will ultimately deliver substantial energy savings for all lighting users and position U.S. companies for technology leadership in global markets for new products, systems, and services.

#### Sample Projects

The following sample projects highlight the progress made toward improving the efficiency, longevity, manufacturability, and cost of SSL technology. For more information on each project, visit the Lighting R&D Web site at www.eere.energy.gov/buildings/research/lighting.

## Cree Lighting Company: LED Package Efficiency and Brightness

This research partner and Lawrence Berkeley National Laboratory are working on a three-year project developing high-radiance LEDs and improved packaging technology. The research team is exploring optical modeling, device simulation, fabrication, and characterization of device prototypes to assess the impact of various design modifications on chip performance. These modifications are studied in prototypes to determine how various materials and design

geometries affect heat dissipation and light output from a compact LED source.

## General Electric: OLED Durability and Performance

Research and Development
Group, with Cambridge Display
Technology, is conducting a
three-year program to reduce
the technical risks preventing the
lighting industry from embracing
OLEDs. In the initial years of
the project, GE developed a
manufacturing process for OLED
devices up to 36 inches square. In
this final year, the research team will
scale-up these techniques for OLED
devices approaching 4 feet square.

#### Lumileds: LED Substrates and New Materials

This research partner is working with Sandia National Laboratories to improve the efficiency of gallium-nitride alloy LEDs for white light production. The team is focusing on low-defect materials, developing diagnostic tools to

study alloy preparation methods, and identifying new white light LED phosphor-like materials.

## Maxdem: SSL Phosphorescent Emitters

This research partner is developing a new family of highly efficient phosphorescent emitters that generate white light from a single-layer OLED. The development of lower-cost phosphors will help overcome a major barrier to widespread application of SSL.

#### Nanocrystals Technology: LED Phosphor Performance

This project will use a new class of nanophosphors (very small phosphors) to efficiently absorb and simultaneously convert UV/blue light to white light. When fully optimized, the nanophosphors are expected to increase white light emission by 100 percent. The high efficiency of these nanophosphors would reduce the cost of white LED lamps considerably without sacrificing performance.



#### Intelligent Optical Systems: General Illumination Using Dye-Doped Polymer OLEDs

This project evaluates molecularly doped, or treated, OLEDs. Tests will explore the use of novel combinations of organic dyes and polymer hosts, which are expected to lead to substantial increases in OLED efficiencies.

#### Universal Display: Phosphorescent OLED Technology

Along with Princeton University and the University of Southern California, this research team has developed a new approach called phosphorescent OLED technology (PHOLED<sup>TM</sup>). The team produced OLEDs that are four times more efficient than previously thought possible. The team is now pursuing two approaches to broadband white light generation based on PHOLED technology: (1) a series of striped red, green, and blue PHOLEDs; and (2) single- and double-doped OLEDs. Both approaches have the potential to lower the manufacturing cost of high-quality, white OLEDs.

#### University of California-San Diego: Novel LED Phosphor Research

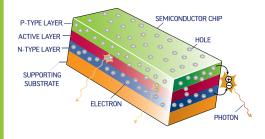
This research partner has discovered and developed a single-composition white-emitting phosphor for SSL applications. By enhancing the red and green light emissions with this phosphor, an energy-efficient, white light emitting LED phosphor is envisaged. The research partner has also shown that a blend of three phosphors is another approach to improving LED lighting quality.

#### University of California-Santa Barbara: Novel LED Structures

Together, this research partner and the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute are exploring the fundamental issues associated with nitride-based SSL. UC Santa Barbara is concentrating on vertical cavity emitting structures, while the LRC is investigating challenges in packaging, testing, and evaluation of nitride-based solid state lighting.

#### Efficient Production of Light

When efficiency goals are met, SSL will produce light with less heat than any other source. At the heart of an SSL device is a sandwich of semi-conductor layers, built on a substrate. Electrons released from the negative n-type layer combine with holes from the positive p-type layer. These electron-hole pair recombinations produce photons, which are emitted from the active layer.



An LED is a very small (dot-sized) electrical device that produces light through the semi-conducting properties of its metal alloys. An OLED is similar to an LED, but is a smaller, surface-shaped device. An OLED is composed of small molecules or polymers that emit light.



Photos provided by (left to right): General Electric, Cree, University of California– San Diego, Intelligent Optical Systems, Intelligent Optical Systems, Lumileds

## To Participate in Solid State Lighting

Does your company, research institution, or university have a promising solid state lighting technology that will save energy? If so, your efforts may be eligible for funding of up to 80% toward development. To learn more, visit www.netl.doe.gov/ssl. Successful proposals are selected based on the potential benefits of the proposed technology. Visit www.eere.energy.gov/buildings/research/lighting for more information on lighting research and development activities sponsored by DOE. To view reports and program planning documents on lighting and other building technologies, visit www.eere.energy.gov/buildings/documents.

### A Strong Energy Portfolio for a Strong America

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Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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